Track Etched Membranes for Electronic Applications

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Abstract: ***Track etched membrane due to its simplicity, small geometry, controllable diameter and length of pores and permanent maintenance of nuclear records offers many exciting applications in various fields of science and technology. Track etched pores produced by physico - chemical treatments to thin films of polymers irradiated by heavy ions can be sequentially deposited by any material to form nanostructures viz. nanowires or nanotubules. Metallic as well as semiconducting nanowires are the most attractive materials having tremendous applications in nano-electronics, magnetic devices, chemical and biosensors, which combining with lithography form different types of novel transistors, micro/nanocapacitors, magnets, transformers whereas nanotubules have more potent applications in physical and biosciences. In the present paper using track etched membranes as template synthesis of nano/micro homogeneous and heterogeneous structures produced using scanning electron microscope for their use in electronic applications.***

Keywords: Track etched membranes, Polymers, Applications, Electronics

1. Introduction

The recent years, there has been tremendous growth in the development of electronics components. The active area of interest lies in potential applications of metallic as well as non-metallic nano/microstructures and materials. Nanotechnology has brought revolution in the development and advancement in the synthesis and fabrication of sensors and devices. Track etched membranes became the precursors to the development of nanotechnology during 1990s.

Track etched membranes also known as ion track membranes (ITMs) besides their utility in microelectronics, find immense applications in areas such as materials science. In materials science, ITMs act as templates [1]-[16] for the deposition of desired materials leading to the development of nano/micro-structures. Such structures may be used as field emitters [15], micro diode arrays [5], conducting polymeric fibrils [8], super-conducting wires [16], magnetic data storage devices [17], transparent metal microstructures [9] etc. Ion track membranes filled with photosensitive materials may also act as flexible solar cell panels [11]. In bio-medical applications, ion track membranes can be used to synthesize polymeric microcapsule arrays for enzyme immobilization for use in biosensors and bioreactors [8] besides their use as filters. Such membranes also play important role in drug delivery devices. In chemical sciences, template synthesized nano/microstructures can be used as pH sensors and as an accurate measuring device for minute solute concentration in solutions [11].

Further, the ion track membrane based template synthesis leads to the generation of nanomaterials[10]-[14]. There is now an extensive curiosity being exhibited in the elemental understanding of nanomaterial properties and in their potential use for technological applications in diverse areas [18],[19]. In the present work, copper nanowires were electrochemically synthesized using etched pores in polycarbonate ion track membrane. Morphology of electrodeposited copper nanowires has been studied using scanning electron microscopy. These nanowires have uniform diameters of about 250 nm, which corresponds to the pore size of the templates used.

2. Materials and Methods

Ion track membranes (ITMs) are produced by physico-chemical treatments to thin films of polymers and mica irradiated by heavy ions. The chemical etching of irradiated films leads to the formation of fine hollow channels along the path of charged particles due to preferential etching along the latent trail. If the thickness of the sheet is less than the particle range in it, the above process leads to the formation of the fine pores in the irradiated sheet. The porosity of the membranes can be controlled by ion characteristics and etching parameters like etching time, etching temperature and etchant concentration etc. [20],[21]

The dimensions of pores depends upon different factors viz. nature and energy of the incident ions, the target materials, etching conditions etc. [20],[1] The method used for the development of micro/nanostructures is template synthesis. In this technique, materials can be deposited with in the template membranes by electrochemical reduction of appropriate metal ion. This technique is based on earlier work of Possin, Willliams and Giaordano, Penner and Martin and Chakarvarti and Vetter [22]-[25] producing thin metal wire. The generated structure can both be homogenous or heterogenous depending upon the pore size and geometries, with complete control over aspect ratio (length and diameter ratio).

3. Experiment

In the present paper, the polymer (Makrofol-KG) having thickness 10µm, irradiated with heavy ion U^{238} having fluence 10^8 ions/cm^2 at normal incidence at UNILAC, GSI, Darmstadt, Germany. These samples were chemically etched at etching temperature 27^{0}C, for 10 minutes in etchant 6N NaOH solution. The microphotograph of pores is shown in Fig.1

Figure 1: Microphotograph of multipore ^{132}Xe (14.5 MeV/u) ion track pores size (~13.3 µm) and (~3.5µm) of single pore in Makrofol-KG.

A thick copper layer was sputtered onto one side of the ITM which acts like a cathode in two electrode electrochemical cell where as pure copper rod act as an anode. The electrolyte consisted of an aqueous solution of 200 g/l $CuSO_4.5H_2O$ and 25 g/l H_2SO_4. High concentration of $CuSO_4$ is important to provide a sufficiently large number of copper ions inside the pores during the galvanic deposition process. Electrodeposition was performed potentiostatically at room temperature i.e 38±1°C. During the deposition process, we recorded the electrical current as a function of time. Fig. 2 shows the current versus time graph during electrodeposition process.

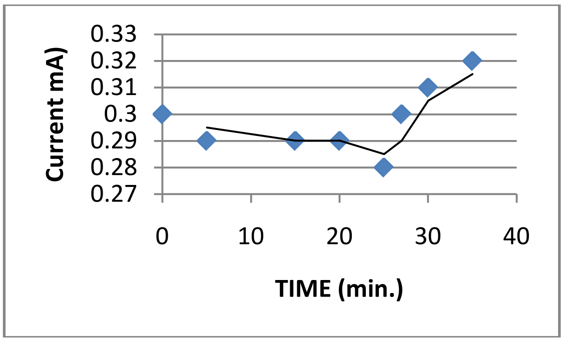

Figure 2: Variation of current versus time during electrodeposition.

After the deposition the polycarbonate templates with Cu nanowires were immediately removed from the electrolyte, first rinse with double-distilled water and ethanol, finally dried in dry air at room temperature. The porous polycarbonate membrane was removed by dissolving it in dichloromethane for 10 minutes and subjected to further analysis. The cleaned and dried samples were mounted on specially designed aluminium stubs with the help of double adhesive tape, coated with a layer of gold palladium alloy in Zeiss, Fine Sputter coater and viewed under "Carl Zeiss Supra 55 Scanning Electron Microscope" at an accelerating voltage of 10 KV. The nanostructures of copper (Cu) grown through the single and multipore ITFs of Makrofol-KG are shown in Figures 2 and 3 respectively. Voltage-Current characteristics of copper grown structures is shown in Fig.5. The 3-dimensional heterostructure of Cu-Se was grown using electrolytes of $CuSO_4.5H_2O$ + 25% of dilute H_2SO_4 and $Na_2SeO_3.5H_2O$ by template synthesis technique. The X-ray diffraction pattern (Fig.6) clearly shows the peaks due to Cu-Se heterostructure and metallic Cu.

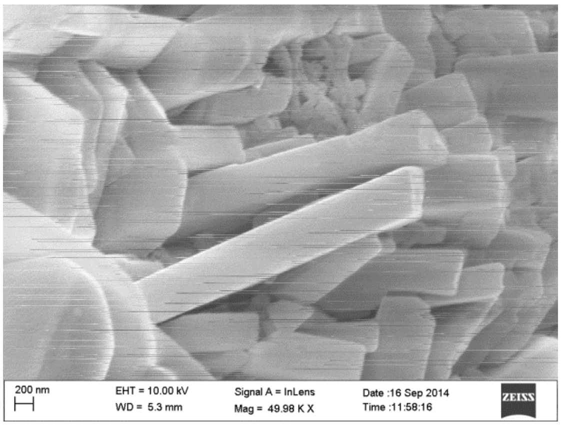

Figure 3: Nanostructure (scanned by SEM) ensembles of Cu grown electrochemically through multipore filters of Makrofol-KG

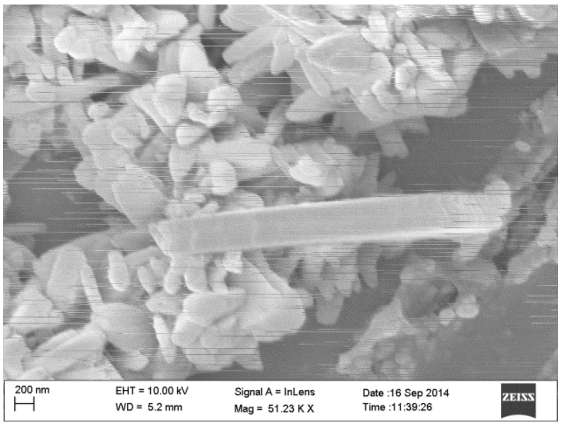

Figure 4: Nanostructure (scanned by SEM) ensembles of Cu grown electrochemically through single-pore of Makrofol-KG

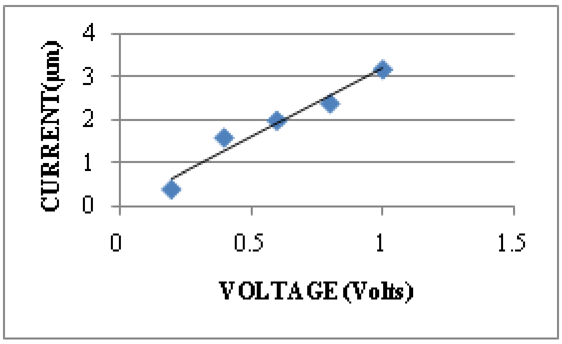

Figure 5: Plot of V-I characteristics of Cu grown structures

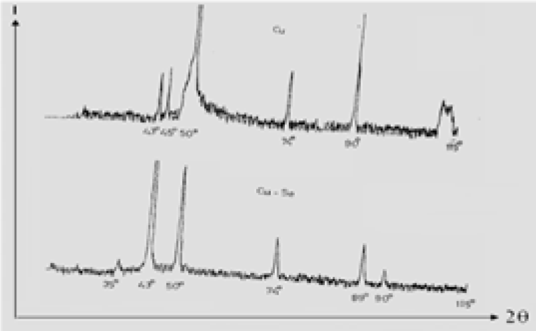

Figure 6: X-Ray diffractogram of Cu and Cu-Se heterostructures showing different peaks

4. Result and Discussion

Images were recorded on the Compact Disc for various magnifications. Fig.3&4 represent SEM micrographs of electrodeposited copper nanowires. The ITMs offer distinct advantages for their use as templates for the generation of nano/microstructures over other membranes like alumina membranes, nanochannel array glass membranes, etc. This is because in ITMs, pore density, pore shape and aspect ratio can be controlled [20] as per the specific requirements by suitably choosing incident ion beam from the accelerator and the etching The morphological study of such structures produced through electrochemical methods provides the finest and critical details of the geometry and dimensions of micro structural constituent elements and as a by product it enables to study the various aspects of interaction of a nuclear particle with given material leading to formation of tracks in ITM. It is well known that parameters, which control the shapes of tracks in ITMs, include the nature of the material; the ion beam and energy deposition rate; pre, post-irradiation storage and environment and the etching conditions.

5. Conclusion and Future scope

As the shape of the wires directly reflects the geometry of the pores in the polycarbonate, the homogeneous copper nanowires can be used in many applications viz. field emission arrays, these conducting nanowires in contact with semiconducting substrate form Schottky nanodiodes, nanoscopic thermocouple can be produced by appropriate material choice for both nanowires and substrate. Sequential deposition combining with lithography enables to form different types of electronic devices and sensors. Many advanced applications of etched tracks have been reported such as formation of nanosized or microsized diodes [26],[27],a light emitting diodes [28] and many electronic devices viz. micro/nano capacitors, magnets, transformers, transistors etc.[29],[30]

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